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1 **Title:** The associations between urbanicity and physical activity and sitting time in Mexico

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22 **Abstract**

23 **Background:** Approximately 17.4% of people in Mexico self-report physical activity levels
 24 below the World Health Organization’s guidelines and an average sedentary time of 16 hours
 25 per day.¹ Low physical activity has been associated with non-communicable disease risk
 26 factors and previous research suggests that urbanicity might be an important determinant of
 27 physical activity. The aim of this study was to measure urbanicity in Mexico and assess if it is
 28 associated with physical activity and sitting time.

29 **Methods:** A sample of 2,880 men and 4,211 women aged 20-69 was taken from the 2012
 30 Mexico National Health and Nutrition Survey and multivariable linear regression models
 31 were used to examine the association between physical activity, sitting time and urbanicity;
 32 adjusting for sex, education level, socioeconomic status and Body Mass Index. The
 33 urbanicity score and the seven urbanicity sub-scores were estimated from the CENSUS 2010.

34 **Results:** The sub-scores of demographic, economic activity, diversity and communication
 35 were negatively associated with physical activity. Sitting time was positively associated with
 36 the overall urbanicity, and the demographic and health sub-scores.

37 **Conclusions:** There was evidence of associations between urbanicity and physical activity in
 38 Mexico.

Introduction

Low levels of physical activity are a current global public health issue.² Along with prolonged bouts of sitting, low physical activity is associated with an increase in the risk of non-communicable diseases such as overweight and obesity.^{3, 4} In the National Survey of Health and Nutrition in Mexico, 17.4% of people self-reported physical activity levels below the World Health Organization's guidelines (150 minutes of moderate-intensity physical activity (MPA) or 75 minutes of vigorous-intensity physical activity (VPA) per week)⁵ and 82.6% spent an average of 260 minutes of MPA or 118 minutes of VPA per week and 3.5 hours per day sitting in front of a screen.¹ In the quarterly survey from the Module of Sport and Physical Activity (MOPRADEF by its initials in Spanish) in Mexico, 54.6% of people reported low levels of physical activity, 27.5% reported having never been involved in any regular physical activity and 43.8% of people who consider themselves as "active" did not meet the WHO's guidelines.⁶ Several attempts have been made by the Mexican government to increase physical activity,⁷ but there is a lack of information about the key factors that are associated with physical activity in Mexico. Previous research has studied the association between physical activity and different aspects of urbanisation (e.g., urbanicity, built environment, urban sprawl). Urbanicity is defined as "the impact of living in urban areas at a given point in time ... the presence of conditions that are particular to urban areas or present to a much greater extent than in non-urban areas".⁸ Urbanicity has been estimated in a variety of ways including rural-urban dichotomy, population size and population density.⁹ More recently, tools have been developed to provide a more comprehensive measurement of urbanicity, incorporating variables such as economic activity, communications, education, infrastructure and social services.^{10,11,12} Features of the built environment such as the perceived proximity to shops and recreational facilities, street connectivity, and aesthetic qualities

of a place are positively associated with physical activity.^{13,14} A number of studies have also suggested that areas in which buildings are within close proximity to one another, and that facilitate walking between locations, are associated with greater physical activity.¹⁵

Existing evidence suggests that the association between urbanicity and physical activity may differ in developing and non-developing countries. In developed countries, a positive association between physical activity and urbanicity has been found. For example, a cross-sectional study in Belgium found a positive relationship between adults' physical activity and environmental variables (quality of sidewalks, accessibility to public spaces, public transport, activity facilities outside home),¹⁶ while a study in United States found that adolescents living in urban areas reported more minutes of moderate-to-vigorous physical activity per day than adolescents living in rural areas.¹⁷ In contrast, cross-sectional studies in Sri Lanka, India and Uganda have found a negative association between urbanicity and physical activity.^{10, 18, 19} Another example of the association between physical activity and urbanicity is China, in which the rapid urbanisation from the last six years has been associated with 68% greater odds in men and 51% greater odds in women of having light (less active) versus heavy (more active) occupational activity.²⁰ Mexico is a developing country with extensive variation in urbanicity, from rural communities in Chiapas and Guerrero to urban cities such as Mexico City and Monterrey. Even though to the best of our knowledge no previous research has examined the association between urbanicity and physical activity in Mexico. Evidence in Mexico suggests that high residential density and street connectivity (measured as intersection density or few cul de sacs) represent a barrier^{21, 22} for physical activity and that the combination of mixed land use with residential density is negatively

associated with all physical activities²³. The aim of this study is to measure urbanicity in Mexico and assess its associations with physical activity (walking time, MPA and VPA) and sitting time.

Methods

The data for this paper were obtained in 2014 from multiple datasets to provide a national picture of physical activity and urbanicity in Mexico. Data from the National Institute of Statistics and Geography (INEGI),²⁴ the Public Education Department (SEP),²⁵ and the National Council of Politics and Social Development (CONEVAL)²⁶ were used to calculate state-level (n = 32 states) urbanicity scores based on previous work by Novak et al. (2012) and were then merged by locality with physical activity data from the National Health and Nutrition Survey 2012 (ENSANUT).²⁷ The anonymised data sets are publicly available from the webpage: <http://ensanut.insp.mx/basesdoctos.php> and participants provided informed consent.

Study Population

The study population was determined by those individuals with physical activity and sitting time variables in the ENSANUT (2012) survey. The ENSANUT survey was collected between October 2011 and May 2012, it is representative at state and national level. Fifty thousand and five hundred households were selected from each state in Mexico using data from the CENSUS 2010, resulting in 96,031 participants, from which a sub-sample (n = 13,009) of 5,459 men and 7,550 women aged 20-69 self-reported their physical activity. Participants had complete data for MPA, VPA, walking and sitting time. Other variables such as self-reported weight (Kg), height (m), calculated BMI (Kg/m²), educational level and socioeconomic status were also reported.

106

107 **Assessment of Physical Activity**

108 The variables of MPA (minutes per week), VPA (minutes per week), walking time (minutes per
 109 week) and sitting time (minutes per week) were derived from the short form of the International
 110 Physical Activity Questionnaire (IPAQ).²⁸ The outcome variables were analysed as continuous
 111 and were processed according to the Guidelines for Data Processing and Analysis of the
 112 International Physical Activity Questionnaire (IPAQ) – Short Form.²⁹ The short form of the
 113 IPAQ has a moderate reliability ($r=0.55$, $p<0.001$) and weak validity ($r=0.26$, $r=0.31$, $p<0.01$) for
 114 assessing moderate and vigorous physical activity among Mexican adults.³⁰

115

116 **Assessment of Urbanicity Level**

117 Urbanicity scores were estimated for the 32 Mexican states using the measure developed by
 118 Novak et al. (2012) and data from the CENSUS 2010, the Public Education Department, and the
 119 National Council of Politics and Social Development in Mexico. The overall scores comprised
 120 seven categories: (1) demographic (either based on population size or on population density), (2)
 121 economic activity (percentage of people involved in agriculture as a primary source of income),
 122 (3) built environment (amount of blocks with paved roads, households with sewage services and
 123 flush toilet), (4) communication (percentage of households with television, mobile phone,
 124 internet and blocks with pay phones in all their roads), (5) education (amount of preschools,
 125 elementary schools, secondary schools, universities and average of women's education), (6)
 126 diversity (households with floor made of ground and inhabitants per room), and (7) health
 127 (number of doctors per inhabitant, amount of medical units and access to health services).¹² For

each participant, an urbanicity score was given according to their state. Two overall urbanicity indices were computed by summing the seven sub-scores where the Demographic sub-score was measured as population size (Overall urbanicity 1) and as population density (Overall urbanicity 2). The rationale for doing this is that in Mexico there are large rural areas that would have a similar population size compared to small urban cities, suggesting that for Mexico, population density might be a better indicator of urbanicity. More detailed information on how the sub-scores were computed can be found as a supplementary file.

Statistical analysis

Statistical analyses were performed using STATA, Version 13 (Statacorp, College Station, TX). Datasets of physical activity and urbanicity were merged according to locality of each participant. Descriptive statistics were calculated for all variables. Linear regression models were used to examine the association between physical activity (outcome) and urbanicity (exposure). Sixteen models were run with MPA, VPA, walking time and sitting time as outcomes. For each of the four outcomes there were four separate models. In the first group (Group I) there were simple and multivariable models where demographic was measured as population size. In the second group (Group II) two further models were run (simple and multivariable) where demographic was measured as population density. All models were adjusted for participant sex, education level, socio-economic status and BMI and were checked for multicollinearity using the variance inflation factor. Although there was some evidence that the outcome variables were skewed, further analysis indicated that the residuals from all models were normal and as such all analyses presented include the original variables without transformation.

Results

Descriptive statistics are presented in Tables 1 and 2. The mean age (\pm SD) of participants in 2012 was 41.26 ± 13.53 years, with a mean BMI of 28.78 ± 5.71 (Kg/m²), an educational level in which 23.88% of the participants ($n = 7,091$) had elementary studies or lower, 50.30% lower secondary studies and 34.23% upper secondary studies; and a socio-economic status in which 30.40% of participants reported low socio-economic status, 35.37% medium and 34.23% high. Participants reported an average of 255.21 ± 316.78 minutes per week of MPA, 117.55 ± 260.98 minutes per week of VPA, 214.20 ± 257.22 minutes per week of walking and 1470 ± 1132.98 minutes per week of sitting time. The mean variance inflation factor for the multivariable regressions was 1.74 for the regressions from Group I and 2.05 for the regressions from Group II, and the tolerance greater than 0.1, meaning that the urbanicity sub-scores are moderately correlated.

Models in Group I are shown in Table 3. In the simple linear regression models, for every unit increase of overall urbanicity (when measured as population size) there was a mean decrease of 2.08 minutes per week of MPA (95% CI = -3.90 to -0.27), a decrease of 3.60 minutes per week of VPA (95% CI = -5.03 to -2.17), and an increase of 14.38 minutes per week of sitting time (95% CI = 8.18 to 20.58). In the multivariable linear regressions, a negative association was found between the demographic and communication sub-scores and MPA; meaning that a 1 unit increase in demographic urbanicity was associated with 17.10 (95% CI = -32.57 to -1.63) and 12.61 minutes less MPA per week (95% CI = -25.30 to -0.07). VPA was negatively associated

with the economic (coef = -10.58, 95% CI = -17.07 to -4.09) and communication (coef = -11.43, 95% CI = -21.43 to -1.44) sub-scores; and positively associated with the built environment sub-score (coef = 12.35, 95% CI = 2.93 to 21.77), meaning that for every unit increase of the built environment sub-score there is an increase of 12.35 minutes of VPA per week. For walking, a unit increase in the demographic sub-score was associated with 14.48 fewer minutes of walking per week (95% CI = -26.99 to -1.97) and a similar result was found for the diversity sub-score where a unit increase was associated with 11.95 minutes less walking per week (95% CI = -20.31 to -3.59). In contrast, education had a positive association with walking where for each unit increase of the education there was an increase of 6.91 minutes per week of walking (95% CI = 1.48 to 12.33). Regarding sitting time, per every unit increase of the health sub-score there was an increase of 48.52 minutes per week of sitting time.

In the simple linear regression Group II (Table 4), for every unit increase of overall of urbanicity (measured as population density) there was a mean decrease of 1.44 minutes per week of MPA (95% CI = -2.71 to -0.17), a mean decrease of 2.31 minutes per week of VPA (95% CI = -3.31 to -1.32) and a mean increase of 10.42 minutes per week of sitting time. In the multivariable linear regressions from the same group (Table 4.), communication was negatively associated with MPA, meaning that a unit increase of the communication urbanicity was associated with 14.10 (95% CI = -26.66 to -1.53) minutes less of MPA per week. Regarding VPA, the economic and communication sub-scores were associated with 10.60 (95% CI = -17.10 to -4.11) and 12.40 (95% CI = -22.29 to -2.51) minutes less per week respectively. The built environment sub-score was positively related to VPA (coef = 14.75, 95% CI = 4.70 to 24.80). Walking was negatively associated with the diversity sub-score, meaning that a unit increase of diversity was associated

with 11.20 minutes less walking time per week (95% CI = -19.60 to -2.81). Sitting time was positively associated with demographic urbanicity (coef = 17.23 95% CI = 4.18 to 30.28) and health related urbanicity (coef = 69.32 95% CI = 19.95 to 118.70).

Discussion

The data presented in this paper show evidence of associations between some components of urbanicity and physical activity in Mexico but the magnitude of the majority of associations is relatively small. It is important to recognise, however, that in sedentary adults these small differences may be important at the population level. Existing literature has reported an association between physical activity and urbanicity¹³⁻¹⁵, but inconsistency in the measurement of urbanicity in these studies makes direct comparison of these findings difficult. The reason for studying disaggregated urbanicity indicators is that a composite urbanicity score might be masking associations between components of urbanicity and physical activity variables and sitting time.

Previous research suggests a positive association between certain features of the built environment (e.g., presence of sidewalks, availability of recreational infrastructure, walking/cycling routes) and physical activity. A literature review of the influence of physical environment in children's physical activity found a positive relationship between the presence of sidewalks and controlled intersections with children's physical activity.³¹ A literature review in adults found positive associations between several environmental features (e.g., enjoyable sceneries, presence of sidewalks, adequate roads for cycling/walking, and public lighting among

others) and physical activity.³² In the present study, the built environment sub-score refers to the amount of paved roads per block, sewage services and availability of electricity in public areas, and as such, its positive association with VPA supports previous literature. The education sub-score was only positively related to 6.9 minutes of walking per week and not related to any other physical activity outcomes, unlike previous research that has found that access to recreational facilities and schools enhances physical activity.³¹ This might be because the measurement of education is slightly related to built environment features (amount of preschools, elementary schools, secondary schools, universities) which could be responsible of the positive association with walking but not enough to be associated with the other physical activity values.

There was evidence of small negative associations between the physical activity variables and demographic, economic, diversity and communication-based urbanicity. A high score in the economic activity sub-score refers to a higher proportion of people not involved in agriculture, therefore the findings may indicate lower physical activity among people living in more urbanised areas who do not work in agriculture, farming, or fishing for example. This is consistent with previous studies in developing countries in which people living in rural areas had higher levels of physical activity than those living in urban areas.³³⁻³⁵ Diversity and communication sub-scores are closely related to household quality and availability of electricity and internet connection, characteristics that are more frequent in urbanised environments.

Regarding sitting time, its positive association with the overall urbanicity and the demographic sub-score is consistent with previous research. Sitting time spent in TV viewing, in the workplace

and in transport are among the main determinants of adults' sedentary behavior and are more closely related to urban lifestyles³⁶. Moreover, people in jobs requiring manual labor are more likely to spend less time sitting than people enrolled in office jobs.³⁷ The biggest association with sitting time was health based urbanicity. The health sub-score measures the amount of doctors, medical units and access to health services which are more likely to be in urban areas than in rural communities. In the results, the mean health score was 4.8, meaning that there are still a lot of opportunities for it to increase as development continues. This could mean that health access is a key urbanicity indicator as it is so fundamental to communities. Supporting this idea, the correlation between the health sub-score and the overall urbanicity is 0.47, which indicates a medium correlation between the variables.

Strengths and limitations

Strengths of the study include the use of a large sample that is representative at state level in Mexico, the combination of different databases from the Government and a comprehensive measure of urbanicity. The identification of both positive and negative associations between the different components of urbanicity and physical activity suggest that there is merit in studying these disaggregated components in order to prevent the potential masking of associations that may occur if only overall urbanicity is considered. Limitations include the possibility of over-estimates of self-reported physical activity and some research has questioned the reliability of the IPAQ in measuring physical activity in developing countries.³⁸ Moreover, studying state-level measures of urbanicity and individual measures of physical activity may fail to account for individual-level detail in terms of the immediate environment in which participants live. For example, the measure of urbanicity used could not capture more fine-grained features of the

immediate environment that could be associated with people's physical activity in Mexico (e.g., street lighting, perception of safety, proximity to parks).^{39,40}

Conclusions

We identified generally small associations between physical activity and state-level urbanicity. The demographic, economic and communication features of urbanicity had a negative association with physical activity while the built environment and the presence of educational facilities had a positive relationship. Overall urbanicity was positively associated with sitting time and this is consistent with previous literature. The other urbanicity variables were not associated with physical activity or sitting, this may be due to limitations in measurement or reflective of a null association between these variables. Future research could focus on studying these associations using individual-level data on physical activity and local data on urbanicity.

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377 **Tables**

378 Table 1. Descriptive statistics of participant physical activity and sitting time

	Mean	SD	Range
BMI (Kg/m ²) (n = 6837)	28.78	5.71	(14.10-64.45)
Education level (n = 7091) ^a	1.01	0.70	(0-2)
Socio-economic status (n = 7091) ^b	2.03	0.80	(1-3)
Moderate physical activity (n = 6946) <i>minutes per week</i>	255.21	316.78	(0-1155)
Vigorous physical activity (n = 6948) <i>minutes per week</i>	117.55	260.98	(0-1200)
Walking time (n = 6945) <i>minutes per week</i>	214.20	257.22	(0-1155)
Sitting time (n = 6904) <i>minutes per week</i>	1470.00	1132.98	(0-6720)

^a Education level: 0 = elementary studies or lower, 1 = lower secondary studies, 2 = upper secondary studies. From 7,091 participants 23.88% had elementary studies or lower, 50.30% lower secondary studies and 34.23% upper secondary studies.

^b Socio-economic status: 1 = low, 2 = medium, 3 = high. From 7,091 participants 30.40% reported low socio-economic status, 35.37% medium and 34.23% high.

Table 2. Descriptive statistics of urbanicity variables in Mexican states (n=32)

	Mean	SD	Range
Demographic 1 ^{a d}	9.89	0.50	(5-10)
Demographic 2 ^{b d}	6.42	2.99	(1-10)
Economic Activity ^d	9.53	1.11	(2-10)
Built Environment ^d	8.91	0.87	(3.36-9.98)
Communication ^d	4.41	1.03	(0.64-8.77)
Education ^d	5.54	1.39	(3.42-9.53)
Diversity ^d	8.95	1.04	(4-10)
Health ^d	4.84	0.60	(2.08-7.93)
Overall 1 ^{a c}	52.10	4.58	(33.22-65.29)
Overall 2 ^{b c}	48.63	6.54	(25.22-65.29)

^a Based on population size.

^b Based on population density.

^c Overall scores can range from 0 to 70.

^d Sub-scores can range from 1 to 10.

Table 3. Group I of linear regression models: Associations between urbanicity, physical activity and sitting time where demographic is measured as population size

Linear regression ^a	Score/sub-score	MPA ^b (n=6946)				VPA ^b (n=6948)				WALKING TIME (n=6945)				SITTING TIME (n=6904)			
		min per week				min per week				min per week				minutes per week			
		Coef.	[95% Conf. Interval]		P> t	Coef.	[95% Conf. Interval]		P> t	Coef.	[95% Conf. Interval]		P> t	Coef.	[95% Conf. Interval]		P> t
Simple	Overall urbanicity 1	-2.08	-3.90	-0.27	0.02	-3.60	-5.03	-2.17	0.00	-0.04	-1.51	1.42	0.95	14.38	8.18	20.58	0.00
Multivariable	Demographic	-17.10	-32.57	-1.63	0.03	-11.09	-23.28	1.09	0.07	-14.48	-26.99	-1.97	0.02	24.69	-28.00	77.4	0.35
	Economic Activity	3.37	-4.86	11.60	0.42	-10.58	-17.07	-4.09	0.00	-5.86	-12.52	0.79	0.08	26.77	-1.36	54.92	0.06
	Built Environment	5.48	-6.47	17.43	0.36	12.35	2.93	21.77	0.01	4.89	-4.77	14.56	0.32	36.16	-4.67	77.01	0.08
	Education	3.14	-3.56	9.85	0.35	-2.21	-7.50	3.06	0.41	6.91	1.48	12.33	0.01	16.34	-6.54	39.22	0.16
	Health	8.97	-4.87	22.82	0.20	6.57	-4.32	17.48	0.23	10.50	-0.70	21.70	0.06	48.52	1.34	95.71	0.04
	Diversity	-9.22	-19.55	1.11	0.08	-4.87	-13.02	3.27	0.24	-11.95	-20.31	-3.59	0.00	26.31	-8.96	61.58	0.14
	Communication	-12.61	-25.30	0.07	0.05	-11.43	-21.43	-1.44	0.02	3.4	-6.86	13.68	0.51	-38.61	-81.93	4.71	0.08

^a Simple linear regression models: Overall urbanicity, demographic score measured as population size. Multivariable linear regression models: Seven-urbanicity sub-scores (demographic score measured as population size).

^b MPA: Moderate physical activity, VPA: Vigorous physical activity.

^c All associations adjusted for socioeconomic status, education level and BMI.

Table 4. Group II of linear regression models: Associations between urbanicity, physical activity and sitting time where demographic is measured as population density

Linear regression ^a	Score/sub-score	MPA ^b (n=6946)				VPA ^b (n=6948)				WALKING TIME (n=6945)				SITTING TIME (n=6904)			
		min per week				min per week				min per week				min per week			
		Coef.	[95% Conf. Interval]		P> t	Coef.	[95% Conf. Interval]		P> t	Coef.	[95% Conf. Interval]		P> t	Coef.	[95% Conf. Interval]		P> t
Simple	Overall urbanicity	-1.44	-2.71	-0.17	0.02	-2.31	-3.31	-1.32	0.00	0.53	-0.49	1.56	0.30	10.42	6.10	14.74	0.00
Multivariable	Demographic	-3.29	-7.13	0.53	0.09	-2.09	-5.11	0.92	0.17	1.60	-1.49	4.69	0.31	17.23	4.18	30.28	0.01
	Economic Activity	3.34	-4.89	11.58	0.42	-10.6	-17.10	-4.11	0.00	-5.54	-12.20	1.12	0.10	27.95	-0.19	56.10	0.05
	Built Environment	9.27	-3.48	22.03	0.15	14.75	4.70	24.80	0.00	3.01	-7.30	13.33	0.56	16.18	-27.37	59.74	0.46
	Education	6.38	-1.63	14.40	0.11	-0.17	-6.49	6.14	0.95	4.58	-1.90	11.06	0.16	-2.73	-30.06	24.60	0.84
	Health	4.40	-10.10	18.90	0.55	3.67	-7.74	15.08	0.52	11.61	-0.11	23.35	0.05	69.32	19.95	118.70	0.00
	Diversity	-9.67	-20.04	0.70	0.06	-5.15	-13.33	3.02	0.21	-11.20	-19.60	-2.81	0.00	30.07	-5.31	65.46	0.09
	Communication	-14.10	-26.66	-1.53	0.02	-12.40	-22.29	-2.51	0.01	1.18	-8.99	11.35	0.82	-39.20	-82.06	3.65	0.07

^a Simple linear regression models: Overall urbanicity, demographic score measured as population density. Multivariable linear regression models: Seven-urbanicity sub-scores (demographic score measured as population density).

^b MPA: Moderate physical activity, VPA: Vigorous physical activity.

^c All associations adjusted for socioeconomic status, education level and BMI.